Toll Roads in Texas: Traffic and Welfare Impacts

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Abstract

Facing funding shortfalls for infrastructure construction and maintenance, many urban regions in Texas are setting up Regional Mobility Authorities to build, manage and own new toll roads. Toll roads can have diverse impacts on a region's traffic, land use, and economy as well as its citizens' welfare. Regions have distinct network configurations, spatial and temporal variation in demand patterns, and road user characteristics which affect their response to such roads. This paper seeks to quantify many of these impacts in Texas by consistently modeling and comparing the impacts of adding toll roads to the Austin, Dallas-Fort Worth (DFW) and El Paso metropolitan planning areas. Initial models were calibrated for the Austin region, and these were appropriately adapted to the DFW and El Paso regions. The impact of added toll roads varied by region, but all suggested greatest impacts near the toll roads with welfare improvements falling with distance in DFW and El Paso, and Austin neighborhoods near toll road termini gaining the most.

Key words: Toll Roads, travel demand modeling, welfare, transferability, traffic impacts

Introduction

Roads arguably are the lifeline of most economies. Fast, reliable roads that efficiently move people and goods are vital for sustaining populations and their economic development. Over the years, many urban areas in the US and around the world have grappled with growing demands on their road infrastructure. In the US, the need for capacity expansion has increased enormously. US commuters consistently rank traffic among the top three regional policy issues together with the economy, education, and/or crime. (See, e.g., Scheibal, 2002, Fimrite, 2002 and Knickerbocker, 2000.) Across the board shortfalls in funding for road construction and maintenance have meant that federal, state and local governments are now looking at new methods of infrastructure financing. Toll financing is fast emerging as a viable mechanism to build roads faster than otherwise possible.

Though toll roads may mitigate infrastructure limitations, they can have diverse impacts on a region's traffic, land use, economy and welfare. Toll roads are not without controversy and can be mired in political debate, as in Austin where public resistance to various elements of toll road plans has surfaced (ABJ, 2004). While some toll road projects are enormous successes, others have been perceived as notable failures, such as Germany's toll roads, the Dulles Greenway, Greenville Southern Connector, northern Tampa's toll roads (TRN, 2003a), and Texas's Camino-Columbia tollway (TRN, 2003b). All these aspects underscore the need to carefully model, study and analyze the impacts of adding toll roads to a region's network.

Different regions have distinct network configurations, spatial and temporal variations in demand and road user characteristics. These differences govern a region's response to toll roads, and thereby determine the actual nature of impacts. This paper seeks to quantify many of these impacts by modeling and comparing three different Texas regions on the effects of operating new toll roads: Austin, Dallas-Fort Worth (DFW) and El Paso. These three areas vary in size, demographics and highway patterns. Impacts are expected to vary, offering some lessons about traveler response.

The methodology adopted examines each of the three regions using a common modeling framework that tests response to different scenarios. The paper develops a behaviorally consistent mechanism for predicting traffic and welfare impacts of toll roads on adjoining roads, bordering areas and entire regions. The modeling framework involves use of travel demand models in a feedback arrangement with network equilibrium traffic assignment models. Initial models were calibrated for the Austin region by Kalmanje and Kockelman (2004), and these were adapted to the DFW and El Paso regions. There are challenges to adapting one region's model parameters to another. The following section examines some literature on the extent and impacts of toll roads. The methodology section then discusses literature relevant for model transferability.

Motivation

By the 1980s, many of the roads built in the 1960s were reaching the end of their design lives. Demands for maintenance and new infrastructure increased, and governments faced funding shortages. Governments were reluctant to increase taxes and increasingly deferred maintenance and reconstruction. All these factors lead to the relatively recent resurgence of toll financing as a mechanism for infrastructure addition and maintenance. Advancements in electronic toll collection (ETC) technologies and increased public acceptance have aided the cause of toll roads; and public-private partnerships are evolving to build, finance, operate, own and maintain highway infrastructure. (FHWA, 2003)

There are almost 5000 centerline miles of tolled roads, and 342 miles of tolled bridges and tunnels in the U.S, 3000 of these on the Interstate system. Texas HB 3588 has given a lot of momentum to toll road projects by authorizing use of the Texas Mobility Fund, provision for bonds and CDAs (comprehensive development agreements) and through creation of Regional Mobility Authorities. Toll roads in Texas mean *new* roads or *new* lanes added to the system using a toll-financing mechanism. Texas is currently not planning to convert any existing roads into priced roads using congestion pricing or other forms of tolls. There are more than 20 toll projects currently underway in Texas, amounting to 142 new centerline miles (TxDOT, 2002 and 2004). As of January 2003, 189 additional miles of toll facilities are being considered/planned or already financed for Texas. (FHWA, 2003).

It is rather critical that one predict and analyze the impacts of proposed toll roads before selecting projects for implementation. Like many other transportation policies, toll roads can be expected to have impacts on traffic flows, employment and household locations, economic activity, home values, and traveler welfare in the region. (See, e.g. LRC, 1971, and Shanis et al, 1985.) This paper examines the traffic impacts and traveler benefits of adding new toll roads to the Austin, DFW and El Paso regions. These three regions differ considerably, in size and traffic demand, as well as the extent of their toll road networks. While DFW is a large metropolitan area with an existing tolled network set for expansion, Austin is a medium-sized, congested region planning to add a variety of toll roads in 2007. El Paso is the smallest of the three, with a relatively short toll road planned for 2015.

Methodology

The modeling framework involves use of travel demand models (TDMs) in a full-feedback arrangement with traffic assignment models to predict travel patterns before and after toll roads are added. The TDMs consist of trip generation, destination choice, mode choice and departure time choice for four trip purposes. When placed in a feedback loop with the traffic assignment module, the process converges to produce estimates of travel times, costs, and flows on the network. Based on these results, various measures of toll road success (such as local and regional travel speeds, revenue generation, and welfare impacts) are obtained. Impacts on link flows, trip attractions, and mode shares are all examined. The results compare impacts across the three study regions.

Destination, mode and departure-time choices are the key traveler decisions. Behavioral models were calibrated for the Austin region. It was assumed that native preferences for travel time, cost and attractiveness factors are identical across all three regions. However, the models applied in each of the three regions differ in terms of their alternative specific constants (for mode and departure time), in order to ensure that marginal count totals are met (from locally obtained travel survey data). Moreover, somewhat different values of travel time were used to assign travelers to their respective network routes ($10 per vehicle-hour in DFW and $8 in Austin and El Paso). Also, different departure periods (peak versus off-peak, for example) were specified in the three regions, based on current MPO practices and/or review of trip timing from travel surveys. Finally, trip productions (and attractions) were provided by each of the MPOs, so there was no need to transfer parameters for trip generation. As a result of all this, the TDMs are highly similar across the three regions – but distinct in several fundamental ways.

Data Description

Austin Region

The primary data source used by Kalmanje and Kockelman (2004) for calibrating the Austin TDM (and thus the TDMs used in the other two regions) is the 1998-1999 Austin (Household) Travel Survey (ATS, 1997) conducted by the Capital Area Metropolitan Planning

Organization (CAMPO, 2000 and 2001). CAMPO also provided peak and off-peak travel time skims for each pair of the 1074 traffic analysis zones (TAZs) in the three-county Austin metropolitan planning region. CAMPO's 1997 zonal demographic files provided information on population, jobs (by basic, retail and service sectors), special trip attractors, and median household income, by TAZ. The census data provided information on vehicle ownership and income, for calibrating the trip generation models. Krishnamurthy and Kockelman's (2003) Disaggregate Residential Allocation Model and Employment Allocation Model (DRAM-EMPAL) were used in conjunction with the Austin TDMs to forecast the 2007 base year employment and household distributions for Austin. Kalmanje and Kockelman (2004) provide more details on the Austin data used for calibration.

CAMPO's year 2007 network file totals 8,749 centerline miles (11,827 lane miles). The 2007 Austin network's planned toll roads amount to 489 lane miles, or 4.13% of Austin's total lane miles. These include SH 130 (a relief route for IH35), and extensions on Mopac (Loop 1 North), US 183 North and SH 45 (North and South). Texas Tollways (2002) lists the following tolls for Austin: 12.5¢/ mile along SH 130, 11.5¢/mile along SH 45 North, and 15¢/mile along Loop 1. More recently, CAMPO (2004) has been suggesting tolls between 15¢ to 18¢/mile but the final toll rates may depend on demand. Hence, a simple toll of 15 ¢/mile was assumed here.

Dallas-Fort Worth Metroplex

The North Central Texas Council of Governments (NCTCOG) provided household travel surveys from 1996, zonal demographic files and network data. NCTCOG also provided travel time skims (by automobile and transit), trip production data, truck trips, and external station counts from their 1999 and 2007 model runs. There are 4,813 zones and 61 external zones in the DFW planning region. Zonal-based estimates of households, population, and employment (by basic, service and retail sectors) for the years 1999 and 2007 were also available, along with land area and median household incomes.

DFW received the first of several new toll roads in December 1999. These new toll roads are the President George Bush Turnpike (PGBT), SH121, SH161 and IH 30 High Occupancy Vehicle (HOV) lanes. The Dallas North Tollway (DNT), International Parkway, Mountain Creek Lake Boulevard (MCLB) and Addison Airport Tunnel (AAT) have been around for quite some time, and thus were not considered "new" in the analysis; they are included in the existing network (and are tolled). Since NCTCOG's 1999 network includes only the DNT, AATT and MCLB links, the 2007 DFW road network (31,121 lane miles) is used for this study. However, the TDM year is still considered to be 1999, since that is the year for which all population and employment (production and attraction) inputs are drawn. In the year 2007, the DFW network has 145 tolled links (183.8 lane miles), of which 97 links (150.7 lane miles) belong to post-November 1999 toll roads, namely, PGBT, SH121, SH161 and IH 30 HOV lanes. The remaining tolled links correspond to pre-1999, existing tolled roads (namely, DNT, MCLB, and AAT) and their post-1999 extensions. NCTCOG provided information on fixed entry tolls and per mile toll rates on these various tolled segments.

El Paso Metro Region

The El Paso MPO provided zonal demographic files and network data along with travel time skims (for automobile and transit over a 24-hr period), trip production data, truck trips, and external station counts for the forecast years 1997, 2005, 2015 and 2025. Mode shares for automobile trips (with occupancies of 1, 2 and 3 persons), transit, and walk/bike trips were provided for each of 3 trip purposes (HBW, HBNW, NHB) based on a TDM application with a 24-hour traffic assignment. The MPO also provided proportions of vehicle trips made across the day based on a 1994 household survey and 2002 external station counts. The El Paso region has 660 (internal) zones and 21 external zones. The demographic files contain information on zonal population, employment (basic, retail and service sectors), number of households and zone type (urban, suburban, and rural). Currently toll roads do not exist in El Paso and are therefore not coded in the 1997 and 2005 road networks provided by the MPO. 2015 was chosen as the modeling year for El Paso since the first segment of the Northeast Parkway is expected to be operational by then. The 2015 El Paso network (4,928 lane miles) has just 36.88 lane miles.

Austin Model Development

Using ATS data Kalmanje and Kockelman (2004) developed trip generation (TG) models for four trip purposes [home-based work (HBW), home-based non-work (HBNW), non-home-based work (NHBW), and non-home-based non-work trips (NHBNW)]. Home-based (HB) trip productions were computed at the household level and aggregated to the zonal level. Trip productions for non-home-based (NHB) trips and trip attractions for all trip purposes also were aggregated. External trip productions and attractions were computed from average daily traffic counts at Austin's external stations.

Gupta (2004) calibrated joint multinomial logit models for mode and departure-time (MDT) choices considering four modes (drive alone, shared ride, transit, and walk/bike) and five time periods [Late evening/Early morning (before 7:15 am and after 8:15 pm), morning peak (7:15 am to 9:15 am), midday (9:15 am to 4:15 pm), evening peak (4:15 to 6:15 pm), and evening off-peak periods (6:15 pm to 8:15 pm)]. Her models (for each of the 4 trip purposes) were used in this study and are shown in Table 1 below. (See also Kockelman, et al. 2005 and Kalmanje, 2005 for more details on calibration.)

Table 1. Joint Mode and Departure Time (MDT) Choice Models (by Trip Purpose), as Calibrated for the Austin Region (Adapted from Gupta, 2004)

Parameters	HBW	HBNW	NHBW	NHBNW
Level of Service				
Time (minutes)	-0.0548	-0.0755	-0.1808	-0.1067
Cost (¢)	-0.0098	-0.0158	-0.046	-0.0273
Constants				
Drive Alone Morning Peak	0.3347	0.0844	1.5704	1.0032
Drive Alone Mid-noon	-0.0685	0.894	3.0372	2.6575
Drive Alone Evening Peak	0.2397	0.1872	2.1967	1.2343
Drive Alone Evening	-1.3938	-0.1143	-0.1151	0.6419
Shared Ride Late Evening/Early Morning	-2.4832	-0.6646	-2.3973	0.1802
Shared Ride Morning Peak	-2.3515	-0.5004	-0.609	0.0949
Shared Ride Mid-noon	-2.3179	-0.232	1.0072	1.5179
Shared Ride Evening Peak	-1.7653	-0.3273	-0.1476	0.9241
Shared Ride Evening	-3.5061	-0.6731	-1.6553	0.5019
Transit Late Evening/Early Morning	-5.156	-4.4493		
Transit Morning Peak	-5.3211	-3.6438		
Transit Mid-noon	-4.773	-2.7827		-6.1271
Transit Evening Peak	-5.2257	-4.0821		
Transit Evening		-5.0853		
Walk/Bike Evening/ Early Morning		-2.1292		-1.4941
Walk/Bike Morning Peak	-2.5062	-1.5052		-1.8209
Walk/Bike Mid-noon	-3.0591	-0.8871	0.9885	0.403
Walk/Bike Evening Peak	-2.7426	-2.1272	-1.0766	-1.3354
Walk/Bike Evening		-2.3116		-1.4941
Log likelihood	-6190.7479	-15998.2086	-2649.8172	-5271.8404
Log-likelihood with constants	-8742.4662	-20296.0560	-4653.9277	-7627.1100
Log-likelihood ratio index (LRI)	0.2919	0.2118	0.4306	0.3088
Number of cases	3196	7260	1877	2836

Note: All parameters are significant. Drive Alone during Late Evening/Early Morning is the base case.

Based on the MDT choice models (which involve travel time and cost variables), the average value of travel time (VOTT) for Austinites was estimated to range from \$2.35/hour to \$3.36/hour, across each of the four trip purposes. These values, though consistent with other related work on Austin (Krishnamurthy, 2002 and Krishnamurthy and Kockelman, 2003), seem quite low. However, they do represent an average for *all* travelers in the region. (Choices by youths and non-working individuals certainly can bring down the estimates.) And they rely on interzonal trip time and cost matrices, which while reasonable, may not be the times and costs perceived by the travelers, especially since travel times are rather variable in congested areas (from hour to hour) and many users may not perceive full transportation costs.

The TDMs include 4 multinomial logit models for destination choices for the 4 trip purposes which capture accessibilities across modes and times of day through logsums from their corresponding joint MDT choice models. This makes the MNL destination-choice model equivalent to the upper level of a nested logit model with MDT choices nested below. The models used in this paper, as shown in Table 2, are Gupta's (2004) recalibrated versions of Kalmanje and Kockelman's (2004) models, and they reflect improved time and cost skim data as well as improved specifications. (See, also Kockelman et al, 2005.)

Table 2. Destination Choice Model Estimation Results (Source: Gupta, 2004)

Parameters	HBW	HBNW	NHBW	NHBNW
Impedance				
Logsum of generalized costs (over modes and departure times)	0.3618	0.5714	0.1517	0.1521
Zonal Size Measures				
Log(Total Employment)	0.4836	0.2284	0.4003	0.417989
Log(Population)	0.0053	0.0690	0.0409	0.039983
Log(Area)	0.0248	0.1468	0.1398	0.157174
Log-likelihood	-2322	-3743	-2148	-3265
Log-likelihood at equal shares	-3750	-7666	-4119	-6273
Likelihood ratio index	0.3797	0.5112	0.4775	0.4788
# observations	1707	3489	1875	2855

Note: All parameters are highly statistically significant (P value = 0.01) with the exception of the HBW's Log(Area) coefficient, which has a P value of 0.028.

The (systematic) utility of a destination from a particular origin is given by equation (1).

$$V_{ijp} = \beta_{(ls)p} LOGSUM_{ijp} + \beta_{(emp)p} \ln(EMP_j) + \beta_{(pop)p} \ln(POP_j) + \beta_{(area)p} \ln(AREA_j) \tag{1}$$

where EMP_j, POP_j, $AREA_j$ are the (total) employment, population and area at the destination zone j, respectively, and $LOGSUM_{ijp}$ is the logarithm of the sum of exponential expressions for the (i, j) origin-destination pair as shown in equation (2). $\beta_{(ls)}$, $\beta_{(emp)}$, $\beta_{(pop)}$ and $\beta_{(area)}$ are the destination choice model coefficients (on the logsum, zonal employment, population and area terms, respectively). $LOGSUM_{ijp}$ is the expected maximum utility derived across all MDT combinations for that particular destination, and it is a measure of accessibility of that destination j from origin of interest i

$$LOGSUM_{ijp} = \ln\left(\sum_{m,t \in C'_{ij}} e^{\beta_{tp} Time_{ij} + \beta_{cp} Cost_{ij} + \beta_{mtp}} \right) \tag{2}$$

where β_{tp}, β_{cp} and β_{mtp} are the joint MDT model coefficients (on time, cost and the alternative-specific constants, respectively) for trip purpose p, with C'_{ij} denoting the full choice set of all possible MDT combinations for trips originating in zone i and ending in zone j.

Transfer of Travel Demand Models to DFW and El Paso

Many regions face the challenge of not being able to calibrate their own travel demand models, due to technical and financial constraints. They look towards other regions to tap into existing models that can be suitably adapted for their needs. The problem of adapting a model from one region to another has received the attention of both practitioners and academicians since the late 1970s. There are many solutions proposed, and the most effective methods require some recalibration with demographic and travel data for the new region. The transferability of trip generation models is fairly well documented and there are many tools available. NCHRP Report 365 (Martin and McGuckin, 1998) outlines these practices. For trip distribution, commonly done using gravity models, it is fairly easy to take parameters from other regions and recalibrate after a few iterations.

However, mode-choice models (and other choice models) pose some challenges. Atherton and Ben Akiva (1976) claim that a well calibrated mode-choice model should be transferable across regions, as long as the region's aggregate mode shares are matched using appropriate mode-specific constants. Tardiff (1978) strongly recommended re-estimation of alternative specific constants (ASCs) when discrete choice models are transferred across regions, because omitted model variables can greatly affect the values and variability of the ASCs. Further, Atherton and Ben-Akiva (1976) found that the best results were achieved using Bayesian estimation of the ASCs by starting with a prior of model parameters and then updating the estimates using new data.

Fortunately, it is possible to adapt mode choice models from other regions by systematically modifying parameters without recalibration (DFT, 2003). The process involves a few iterations before producing reliable results. Ortuzar and Willumsen (1990) suggest altering the model constants (c) and scale parameter (λ) first before changing the relative values of the parameters (β).

$$V = c + \lambda\beta' X \tag{3}$$

where V is the systematic choice utility, c is the ASC, λ is the scale parameter, β is a vector of slope parameters and X is a vector of explanatory variables (such as time and cost).

ASC values can be computed using population averages for the variables so as to achieve aggregate shares. In this study, population averaging was achieved by weighting the variables using actual trips made based on planning data. For example average interzonal values for the time and cost variables were obtained by weighting the interzonal times and costs with the OD flows. Atherton and Ben Akiva (1976) studied this very procedure among other techniques and found it to lead to reasonable results. Since the technique is relatively easy to adopt, and does not require recalibration, this method was used to adapt the constants in Austin's MDT choice models to the DFW and El Paso regions.

The slope parameters are not altered at any stage thereby implying that people's relative preferences for destination attributes, travel cost and time are constant across the three regions. Only the ASCs in the MDT models, which reflect aggregate shares, were modified. Austin's trip generation models were not transferred. Estimates of trip productions for DFW and El Paso were obtained from their respective MPOs. The destination choice models also were not altered, since they do not possess ASCs. Changing their slope parameters would affect marginal rates of substitution which is not the objective of this study.

Four modes and 5 departure-time periods were selected based on NCTCOG household survey data, El Paso mode shares (from El Paso MPO's TDM results) and time of day traffic distributions provided by the El Paso MPO. 20 MDT combinations were developed and corresponding shares computed using available data. Since data was available only for NHB trip purposes, the same shares were used for both NHBW and NHBNW trip purposes. Next, the MDT model's ASCs for DFW and El Paso were computed by equating aggregate shares and predicted shares using slope parameters from the Austin MDT choice models. Trip-averaged travel time and cost values were assumed while solving for these ASCs. Trip averaging was achieved using NCTCOG and El Paso MPO OD data and travel time and cost skims. There is a unique set of ASCs which make the predicted shares equal the aggregate shares for each choice – as long as the scale parameter in equation 3 is unchanged. This is possible since the sum of all predicted probabilities equals one and there is no ASC corresponding to the base case alternative. Solutions were obtained where the scale parameter also was changed; however, due to a lack of better data, there was no way to select any of these solutions over the one where the scale parameter was unaltered. For more details on development of the joint MDT choice models for DFW and El Paso, readers may refer to Kalmanje (2005) or Kockelman et al (2005). The destination choice models for DFW and El Paso were the same as those used for Austin; however, they rely on logsums from the corresponding MDT choice models.

Model Application

This section discusses the applications of TDM for Austin, DFW and El Paso regions. Feedback equilibrium using the method of successive averages (MSA) and some issues with achieving feedback equilibrium are discussed.

The 2007 demographic inputs to Austin's trip generation models were computed by Gupta et al. (20054) from applying the Austin TDMs in conjunction with DRAM-EMPAL land use models (Krishnamurthy and Kockelman, 2003) in a 5-year feedback loop starting in the year 1997. The Austin TDM application process is described in detail by Kalmanje and Kockleman (2004). Finally, the traffic assignment module of TransCAD (Caliper Corporation, 2002) was used to arrive at a User Equilibrium (UE) assignment of traffic to the network, for each of the 5 different time periods. A generalized cost function [Equation (4)] based on the Bureau of Public Roads' (BPR) volume-delay equation (BPR, 1964) was used in traffic assignment.

$$c_i(x_i) = k_i + \delta L_i + \varphi t_i \left[1 + \alpha_i \left(\frac{x_i}{C_i} \right)^{\beta_i} \right] \quad (4)$$

where $c_i(x_i)$ is the generalized monetary cost of using link i when traffic demand equals x_i, k_i is the fixed (toll) cost for link i, δ is the vehicle operating cost per mile (assumed to be 30¢/mile [Edmunds, 2004 and Strayhorn, 1999]), L_i is length of link i, φ denotes VOTT (assumed to be \$8/hour), C_i is the capacity of link i, and α_i and β_i are link parameters (BPR values of 0.15 and 4 used when values not provided by CAMPO). Since the VOTTs estimated from the mode-time of day choice models were very low (ranging from \$2.35 to \$3.36 per hour), a higher value was assumed for traffic assignment. (See Kalmanje and Kockelman [2004] and Gupta et al [2004].)

The method of successive averages (MSA) was used to achieve feedback equilibrium for the TDM application. (See, e.g., Gupta, 2004 and Gupta et al., 2005.) The process begins by assigning initial origin-destination flows (ODF) to the network to obtain initial equilibrium traffic assignment flows (TAF). For these TAF, link times and link costs are computed using the generalized cost function in equation (4). Interzonal travel times and costs are computed from skimming the network for minimum generalized costs. Based on these zonal times and costs, ODF are computed using the destination choice and the MDT choice models. The new ODF are averaged with the initial ODF to obtain the successively averaged origin destination flows (SAODF). SAODF are assigned to the network to obtain new TAF. The new TAF are then averaged with the initial TAF to obtain successively averaged equilibrium traffic assignment flows (SAETAF). The interzonal times and costs corresponding to these SAETAF are fed back to the TDMs and so on. The process continues until a 0.01 (or 1%) relative gap convergence criterion between SAETAF and the current TAF is met. This resulted in the use of 15 feedbacks for Austin. Transit service level changes were recognized by adjusting transit travel times after every feedback based on the shift in the corresponding auto travel times (i.e. bus times were assumed to fall along with auto times).

The trip productions provided by NCTCOG and the El Paso MPO were used for the 4 trip purposes. Since trip production data was only available for NHB trips as a whole (and not separately for work and non-work trips), the NHB trip productions were equally split to obtain NHBW and NHBNW trip productions. While NCTCOG provided peak and off-peak travel times and distance skims for auto and transit, El Paso's MPO could provide only 24-hour skims for auto and transit modes. These skims were used to initialize the simulations across 5 times of day and 4 modes. As discussed for Austin, cost skims for auto were generated from the length skims using a 30¢/mile conversion. The time and cost skims were used to apply the destination choice models using logsums from the DFW and El Paso MDT choice models respectively. The other inputs to the destination choice models (like employment, population and zonal area) were all provided by the NCTCOG and El Paso MPO. Austin's return trip rates were used to convert P-A matrices to O-D matrices, and Austin's vehicle occupancy rates were applied to obtain vehicle trip matrices for traffic assignment.

Morning and Evening Peak, and 24-hour off-peak capacities were provided by NCTCOG for the network. The off-peak capacities were proportionally divided among the 3 off-peak periods in this study (T0, T2 and T4). User Equilibrium (UE) traffic assignment recognizing the presence of HOV lanes was used. While drive alone and truck trips were excluded from the HOV lanes, shared ride trips are allowed. A $10/hr VOTT was used for DFW during traffic assignment based on NCTCOG values. 11 feedbacks using the MSA procedure were used to achieve for the DFW application.

The El Paso MPO provided 24-hour capacities for the road network. This was converted into 2 hour peak (for peak periods: T1 and T3) and off-peak capacities (for 3 off-peak periods: T0, T2, T4). 20% of 24-hour capacities was assumed for the peak and 25% of the 24-hour capacities for the off-peak. This study assumed a 10 ¢/mile toll on the toll links in El Paso. Actual planning data was not available to determine the toll values. Since El Paso is a reasonably uncongested network, the 10 ¢/mile value was assumed, even though it is relatively low compared to Austin's 10 ¢/mile. Single class UE assignment with the generalized cost function was used just like in the Austin case. The traffic assignment procedure used was UE generalized cost assignment. An $8/hr VOTT was used for traffic assignment, just like in the Austin case. 15 feedbacks using the MSA procedure were used to achieve convergence in the El Paso application.

The next section compares the results obtained for the three study areas before and after toll roads were added to the respective networks. Traffic, traveler welfare and revenue generation impacts are discussed.

Results

A major objective of this study is to understand how toll road impacts vary across a region. These are expected to be a function of distance to the toll roads, as well as regional centers of population and employment. To achieve this objective, two *neighborhoods* or *bands* were constructed around the toll road corridors, at distances of 5 miles and 1 mile. Figure 1 shows these neighborhoods for each of the three Texas regions.

Traffic Impacts

The following section studies traffic impacts of new toll roads across the region and also across different time periods. Table 3 shows the changes in vehicle miles traveled (VMT), vehicle hours traveled (VHT), VMT-weighted mean speeds, and VMT-weighted volume-to-capacity ratios (v/c ratios) both *before* and *after* the addition of the new toll roads. In order to emphasize traffic impacts on the current (before) network links, all results/all neighborhoods in Table 3 exclude the new toll roads.

From Table 3, one sees that the Austin and DFW regions exhibit fairly uniform trends in traffic impacts of the new toll roads. Speeds increase (and v/c ratios fall) as one nears the tolled roads. Regional VMT and VHT values (not including the new toll roads) are predicted to fall. Interestingly, these reductions are greatest in the Austin region, on the roads nearest the toll roads. In contrast, roads nearest the DFW toll road additions are predicted to experience a substantial increase in their current VMT levels, suggesting that route shifts are substantial and will load connectors. These connectors are capacity-constrained and may experience speed reductions, even though VMT and VHT are falling overall (when use of the new toll roads is not included in the calculations). The ELP network was hardly affected at all, with all VMT, speed, VHT & v/c shifts estimated to be less than 1%.

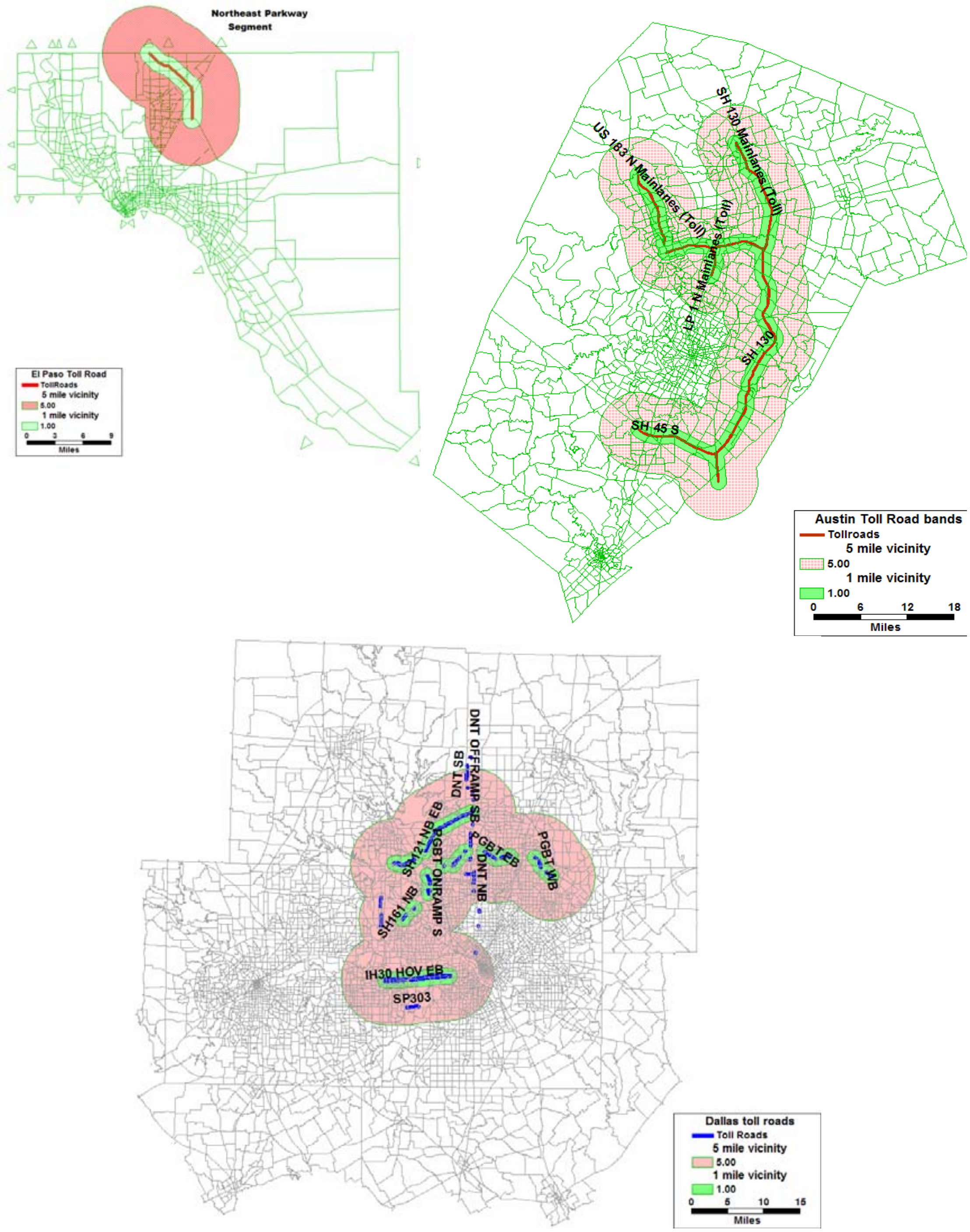

Figure 1. 5-mile and 1-mile Neighborhoods for the El Paso, Austin, and DFW Toll Roads

Table 3. Percentage Change in VMT and VHT on Existing Roads for Different Neighborhoods

Region	VMT/VHT	Percentage Change		
		All roads	*5-mile vicinity*	*1-mile vicinity*
Austin	V/C (VMT weighted)	-0.64%	-2.04%	-6.13%
	Average speed (VMT weighted)	-0.05%	0.05%	0.49%
	Daily VMT	-0.52%	-1.02%	-0.55%
	Daily VHT	-0.53%	-1.10%	-1.20%
DFW	V/C (VMT weighted)	-1.27%	-1.56%	-1.83%
	Average speed (VMT weighted)	0.82%	1.28%	8.93%
	Daily VMT	-0.82%	-1.13%	11.47%
	Daily VHT	-1.69%	-2.41%	0.84%
El Paso	V/C (VMT weighted)	0.41%	0.16%	-0.21%
	Average speed (VMT weighted)	-0.09%	-0.03%	-0.04%
	Daily VMT	-0.01%	-0.08%	-0.29%
	Daily VHT	0.22%	-0.05%	-0.26%

As expected toll revenues are largest during peak periods when volumes are greatest. New toll road revenues are estimated to be just $94/day in El Paso, just $13,221/day in Austin, and a striking $503,984/day in DFW. In DFW, *net* revenues are somewhat lower (i.e., $407,809), due to diversion of some traffic from existing toll roads; nevertheless, the added lanes are expected to be very valuable. Clearly, these revenue results suggest some potentially serious issues for cost recovery in El Paso and even Austin. The revenues translate to $2.54, $27, $3344 per day per lane mile in El Paso, Austin and DFW, respectively, or $928, $9,878 and $1.2 million per lane-mile per year. Assuming a construction cost of $2 million per lane-mile, only the DFW toll roads are predicted by these models to be profitable. In the longer term, of course, growing populations, job relocations and rising VMT may result in revenues additions. In general, these results seem to suggest that the location of DFW's new tollways (centrally, rather than peripherally), the existence of other tolled routes in DFW (some potentially serving as substitutes), and general congestion make for a potentially very profitable tolling scenario in the DFW region. Austin's planned roads extend to the periphery and do not serve highly developed locations. El Paso's planned tollway is on the edge of the region and is quite short. Rather crucially, El Paso's tollway ties into the low-density regional periphery, and is therefore only able to attract and affect a very small proportion of trips. If a larger modeling region/zone system were used, and an IH10 bypass of downtown ELP were to be added as planned, to tie into this toll road (from the north and western side of the region), traffic and revenue predictions could be much higher. In essence, El Paso's current modeling region is probably very inadequate for appraisal of this new road's evaluation.

As one would expect, VMT-weighted average toll road speeds (62 mph, 53 mph, and 42 mph for DFW, Austin and El Paso toll roads) are substantially greater than average speeds on nearby roadways, since these toll roads are designed to freeway standards and are relatively uncongested. However, there are many differences in the nature of traffic impacts across the 3 regions. The congestion reducing impacts in El Paso are quite localized to the 1-mile vicinity of the toll road and to off-peak periods. In contrast, new toll roads in Austin and DFW are predicted to have fairly uniform effects across their regions and across time periods. Differences are expected, of course. El Paso's is a bypass to some extent, and Austin's SH130 is a bypass. Also, most of Austin's toll roads are connected to each other. In contrast, DFW's are largely central, without direct connections to one another.

Of course, added roadways can attract more trips, offering benefits to local businesses, thanks to easier access. Total predicted trip attractions within the 1-mile and 5-mile neighborhoods were computed before and after the addition of toll roads; and the TDMs predicted very slight increases in attracted trips. Only minor variations were observed by trip purpose. Increases are predicted to exceed 1% only in the case of El Paso's 1-mile neighborhood. This suggests that in the short term toll roads may not have a significant impact on trip attractions and that the effects may be greatest for smaller regions, such as El Paso. In the longer term, of course, enhanced access may spur relocations and new land development, alongside the toll roads, resulting in greater trip attractions. The following section discusses another form of impact, on traveler welfare.

Welfare Impacts

Differences in logsums of the TDM's systematic utilities were used to evaluate welfare changes. Ben-Akiva and Lerman (1985) and Small and Rosen (1981) refer to these logsum differences as differences in consumer surplus or compensating variation (CV). A CV measure computed as the logsum difference at the destination choice level (with nested mode and departure time choices) provides a useful and rather comprehensive measure of impact across all destinations, modes and departure time choices. Transit service level (travel time) changes also have been recognized, since bus and rapid transit (DART) times were assumed to fall along with auto times.

Equation 5 gives the CV expression, as a monetarized *difference* in the expected maximum utilities before and after the toll roads are added. It is computed for every origin zone (assumed to be the traveler's neighborhood of residence), with $V_{i,j,p}$ denoting the utility of a trip-maker located in zone i and considering all potential destinations j for a trip of purpose p, with C denoting the full choice set of all possible destinations. (See Equation 1.)

$$CV_{ip} = \frac{1}{\alpha_p}\left(E(Max_j(V_{ijp})^t - E(Max_j(V_{ijp})^n\right) \tag{5}$$

where $E(Max_j(V_{ijp}) = \ln\left(\sum_{j\in C} e^{V_{ijp}}\right)$ (6)

Here, t and n denote the scenarios with and without toll roads, and α_p is the destination choice model's marginal utility of money for trip purpose p.

It can be shown that $\alpha_p = \beta_{(ls)p}\beta_{cp}$, by taking the derivative of Equation 1's V_{ijp} with respect to *Cost*. CV was not computed in the above fashion (Equation 5) for HBW trips since work locations were held constant (for a more appropriate, short-term comparison of traffic impacts – and a more appropriate, and conservative estimate of welfare impacts). Instead, CV was computed for HBW trips using the average monetarized difference in logsums at the joint mode-departure time choice level, holding the work locations constant, as shown in Equation 7:

$$CV_i = \frac{1}{\beta_c} \sum_{j \in C} P(j \mid i) * \left(E(Max_{mt}(V_{mt|ij})^t - E(Max_{mt}(V_{mt|ij})^n \right) \quad (7)$$

where $$E(Max_{mt}(V_{mt|ij}) = \ln\left(\sum_{m,t \in C'} e^{\beta_t Time_{ij} + \beta_c Cost_{ij} + \beta_{mt}} \right) \quad (8)$$

CVs were computed by trip purpose for all three regions, and sample results for HBW and HBNW are shown in Figure 2. In all cases, zones closest to the new toll roads (are predicted to) gain more than those farther away. Benefits are estimated for the great majority of the region's "average" trips (by origin), but these are slight, topping out at 12¢/trip in El Paso and Austin, and 4¢/trip in DFW. Austin trips originating near the intersections or very ends of the toll roads are predicted to benefit most. Simpler relationships are observed in El Paso and DFW, where only a single toll road is being added (El Paso) or the additions are not connected (DFW). In effect, the El Paso and DFW toll roads operated independently, while Austin's form much more of a regional network, producing more complex impact patterns. Interestingly, revenue gains are highest in DFW (by a wide margin) – though welfare changes appear less significant in that region.

Any predicted losses in all three regions are very low (typically less than 1¢/trip), and these generally are visible at the regions' edges, away from the toll roads. They are felt to be biased low, stemming from a divergence in assignment and mode choice value-of-time assumptions rather than from any actual travel disbenefits. Edge effects can also arise, to some extent, from the artificial boundary that constrains travel choices in those zones, permitting less flexible patterns of response (e.g., choosing destinations outside the defined region).

In theory, road additions – even if they are tolled additions – should facilitate trip-making and thus enhance traveler welfare, as measured in this work. These benefits are generally expected throughout a region, though certain responses (such as longer trip-making) may negatively impact some links (such as those close to the DFW toll road additions) and thus some trip making. Therefore, any welfare losses predicted by these models are not immediately intuitive. The use of a higher VOTT during traffic assignment as compared to the choice models is felt to be the reason for this discrepancy. VOTTs for route choice/network assignment were assumed to range from \$8 to \$10 per vehicle hour, while those in choice of mode (and thus destination) were assumed to vary between \$2.35 and \$3.36 person hour. Thus, the first assumption resulted in relatively more traffic assignment to faster, tolled links than was perfectly consistent with time-of-day and destination preferences. So there is reason to believe that these models are consistently underestimating welfare benefits. Moreover, the focus on an "average" traveler, and single VOTT for all is imperfect. In reality, these regions boast a wide range of traveler and trip types.

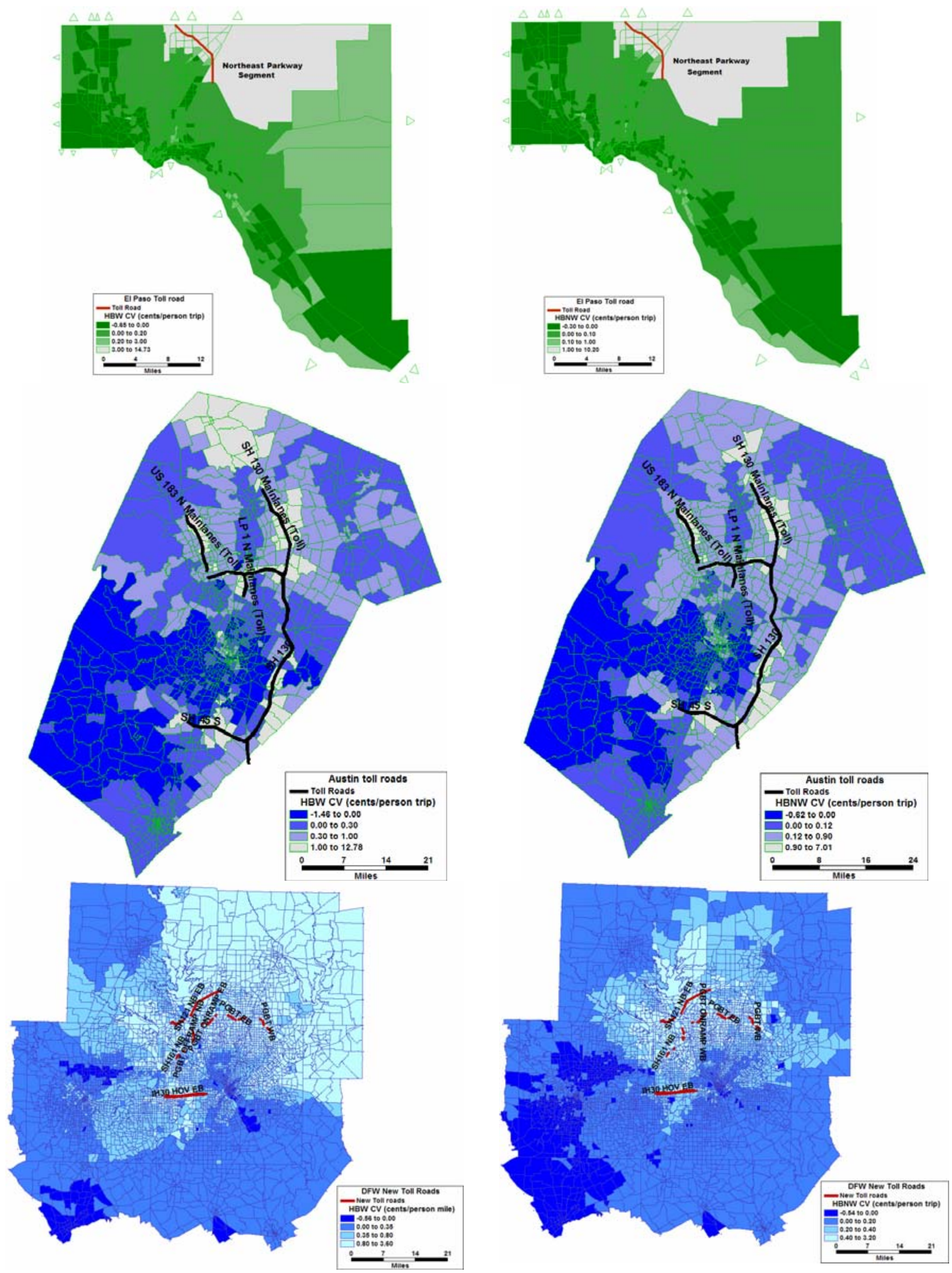

Figure 2. Net Traveler Benefits Following Toll Road Addition in El Paso, Austin and DFW for HBW and HBNW Trip Purposes

Conclusions

This work examined the nature of travel responses to the addition of toll roads in three Texas networks. Models were calibrated for Austin and adapted to the DFW and El Paso regions. These regions differ in size, travel demand and network configuration. As expected, there are variations in their predicted responses to toll roads, but also some general patterns.

Results for El Paso indicate that the gains from congestion reduction are concentrated within a one-mile neighborhood of the toll road, with negligible impacts elsewhere. Traveler benefits are estimated to be largest for zones lying northeast of the toll road, which bypasses the region's downtown. In the Austin case, several new toll roads that facilitate access to the region's core, and mean travel speeds improve rather uniformly, indicating overall system improvement. The resulting distribution of welfare benefits are complex, in contrast to the relatively simple relationships exhibited in El Paso and DFW, where traveler welfare predictions fall rather uniformly with distance from the new toll roads. In Austin, the greatest benefits arise near toll road intersections and ends of the system.

Near-term revenues (per lane-mile) are predicted to be substantial in DFW ($3344 per lane-mile per day) but low elsewhere. Toll road use in El Paso, based on 2015 trip production and attraction values, is predicted to be very minor. But this result may be largely due to the definition of regional boundaries: the new road ends at the boundary, substantially limiting adaptation of interregional and local traffic patterns. Of course, all three regions are growing, and their land uses will evolve over time, to make better use of the access opportunities offered by capacity additions, tolled or untolled. A look at future populations and land use model predictions would enhance these travel demand model applications. Moreover, calibration of the DFW and El Paso travel behaviors based on local travel survey data would add realism and should improve prediction accuracy. Low VOTT estimates arising in the mode-choice models were at odds with those used for network assignment (which were felt to be more reasonable), and this put pressure on the welfare calculations. Ideally, a greater consistency would exist there. Furthermore, multi-class assignment recognizing a variety of traveler types, and behavioral models responsive to a variety of demographic features, are a paradigm that all modelers aspire to. This is a difficult class of problem and research is underway around the world. In the meantime, these models and evaluations of their predictions offer insight into regional responses to tolled capacity additions. The ability to rigorously examine traffic and traveler welfare impacts by neighborhoods is quite valuable and should prove useful to policy makers needing to objectively select toll road projects in the face of often passionate public scrutiny.

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